

Cooperative Lander/Rover-Biomorphic Explorer Mission

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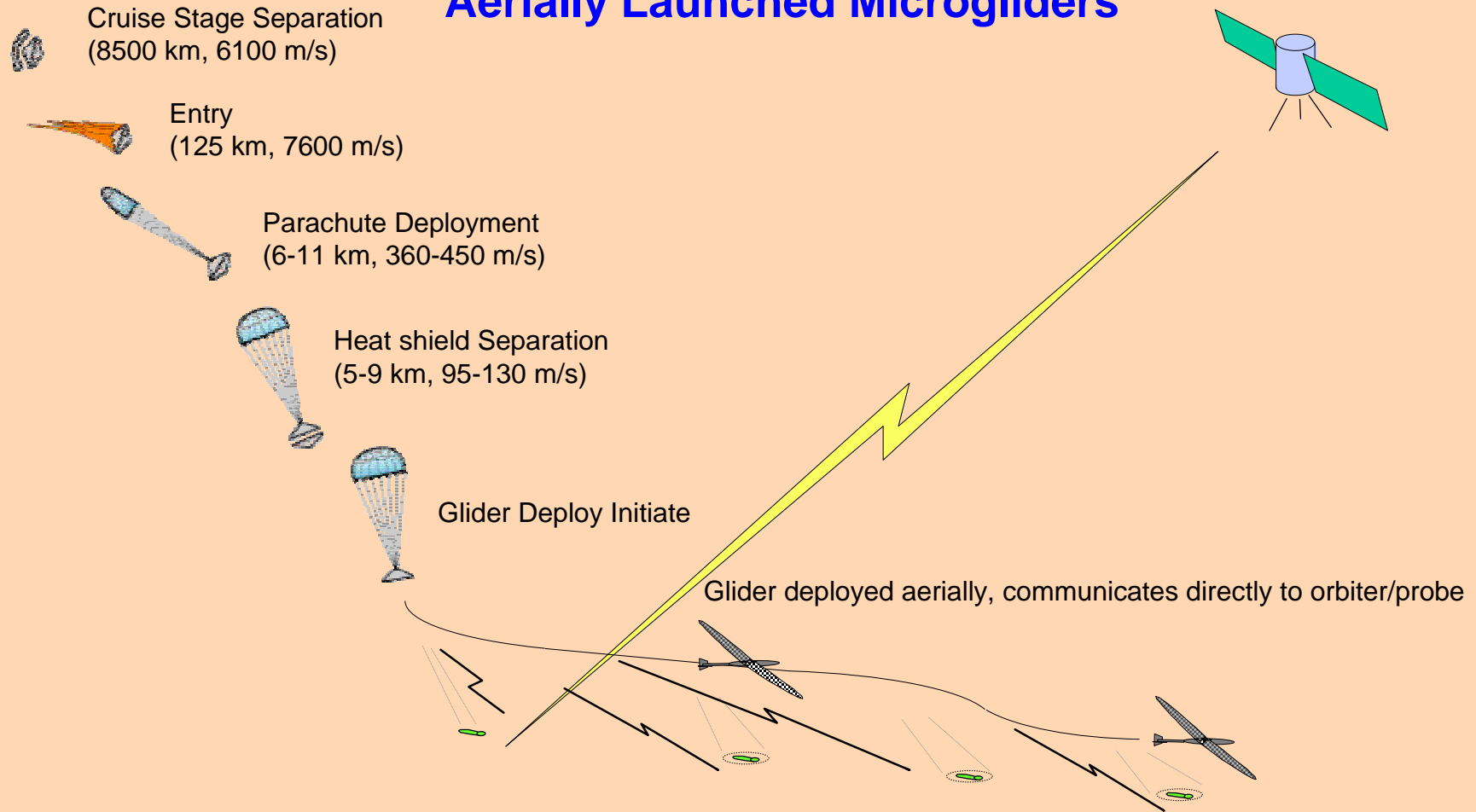
Presentation at the NASA/DoD Second Biomorphic Explorers Workshop

**Bio-inspired Engineering of Exploration Systems 2000
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Science Requirements

- Orbiter provides imaging perspective from ~ 400 Km height with resolution ~ 60 cm to 1 m/pixel; lander mast imagery is view from ~ 1-2 m height, the essential mid range 50m-1000m altitude perspective is as yet uncovered and is an essential science need. Imaging from this mid-range is required to obtain details of surface features/topography, particularly to identify hazards and slopes for a successful mission)
 - Close-up imagery of sites of interest (~ 5 - 10 cm resolution)
 - 1-10 Km range, wide area coverage
 - Distributed Measurements across the entire range
 - In-situ surface mineralogy.
- Candidate instruments include
 - Camera (hazard & slope identification by close-up imagery)
 - Meteorological suite (in-flight atmospheric measurements)
 - Microphone to hear surface sounds, wind and particle impact noises
 - Electrical Measurement of surface conductivity
 - Accelerometer Measurement of surface hardness
 - Seismic measurement (accelerometers)

Aerially Launched Microgliders



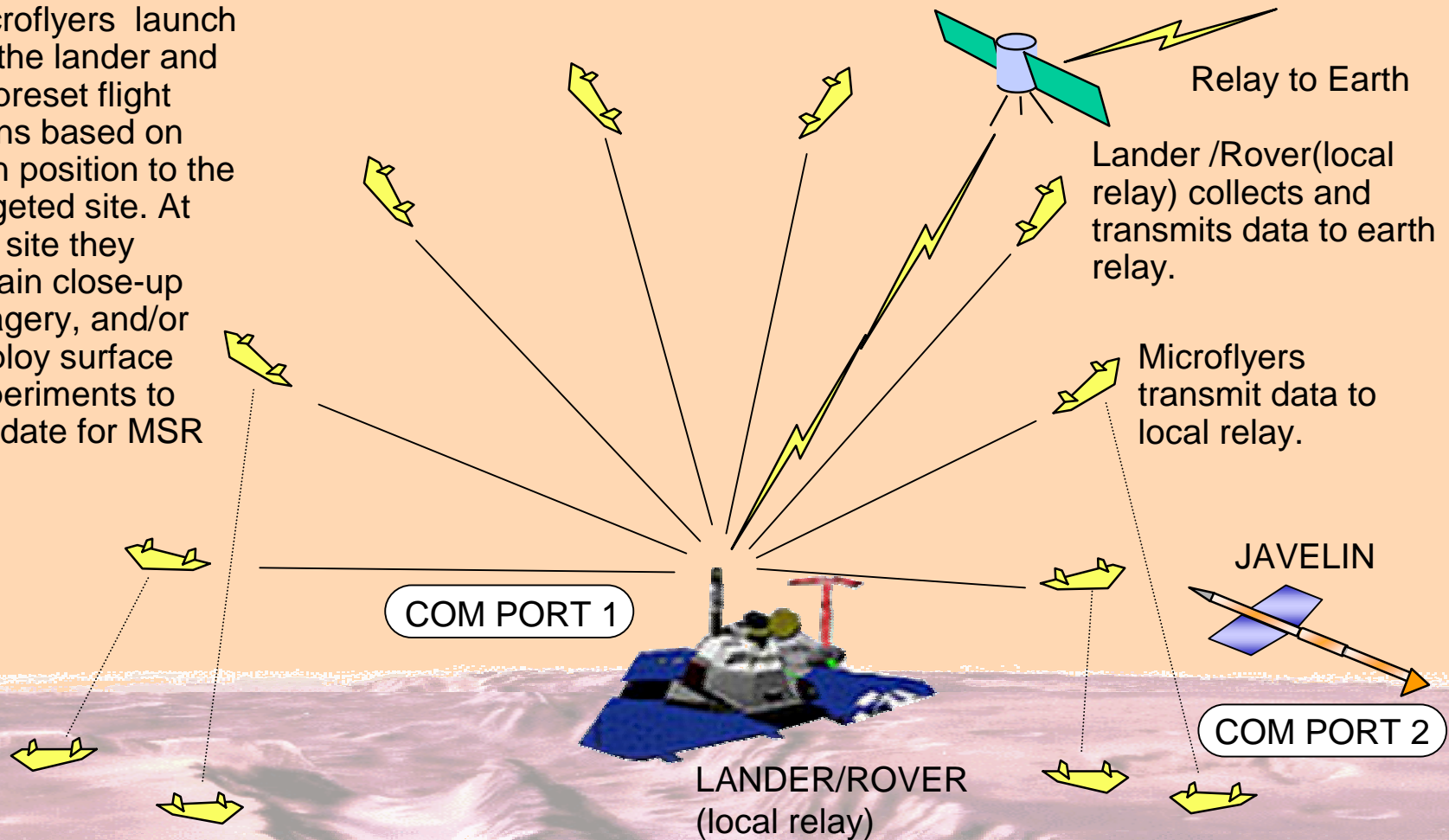
The above scenario has been thought about a lot in the last few years. A high altitude Near Synchronous Orbit providing Long-Dwell service to any point on Mars is necessary/desirable for success on this type of mission. While our telecom infrastructure is still in its infancy, at the current state, a cooperative mission using a Lander/Rover as a robust local relay is proposed in this presentation.

Biomorphic Mission: Cooperative Lander/Rover - Biomorphic Explorers

- An auxiliary payload of a Mars Lander (2-10 kg)
- Micro-gliders (4 - 20) launched or deployed from the Lander or Orbiter
- Lander serves as a local relay for imagery/data downlink
- Micro-Glider provides :
 - Close-up imagery of sites of interest (~ 5-10 cm resolution)
 - Deploys Surface payload/experiments (20g - 500g)
 - In-flight Atmospheric Measurements
 - Candidate instruments
 - Camera (hazard & slope identification by close-up imagery)
 - Meteorological suite (in-flight atmospheric measurements)
 - Microphone to hear surface sounds, wind and particle impact noises
 - Electrical Measurement of surface conductivity
 - Accelerometer Measurement of surface hardness
 - Seismic measurement (accelerometers)
- 50m-500m height, unique and essential perspective for imaging
 - 1-10 km range, wide area coverage very quickly
 - Useful close-up imagery and surface payload deployment
- Future Missions - Competed Scout Missions (2007), Distributed Deployment and in-situ measurements- 2007 and beyond

Lander/Rover-Microflyer Cooperative Mission Surface Launched Microflyers

Microflyers launch off the lander and fly preset flight plans based on Sun position to the targeted site. At the site they obtain close-up imagery, and/or deploy surface experiments to validate for MSR

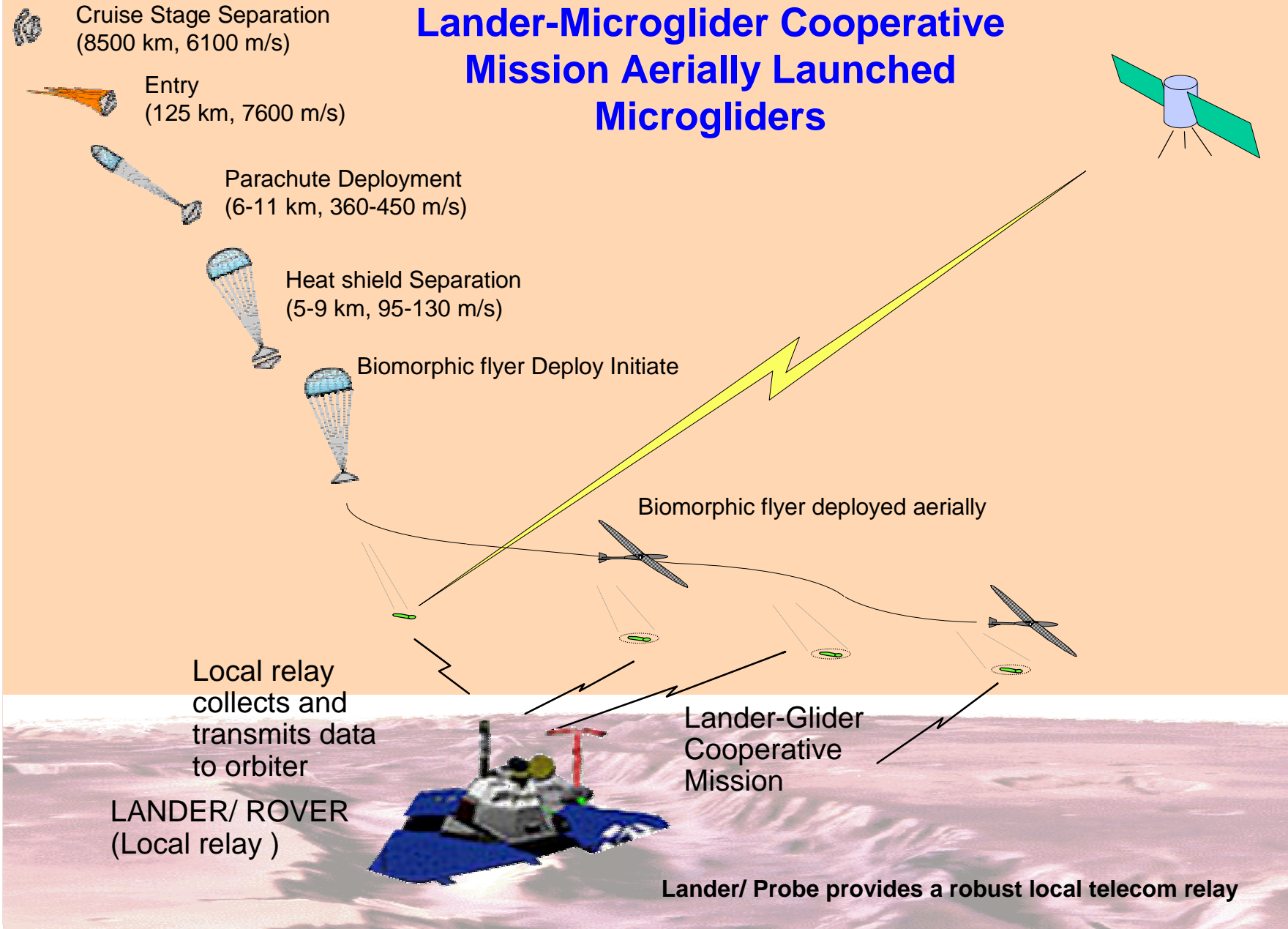


Surface launched micro-flyers work in synergy with the surface systems to enable new science endeavors. Lander/Rover provides a robust communication route for imagery down link from the micro-flyer. A second com-port (javelin) can also be launched from the Lander to assist differential position sensing

Biomorphic Mission: Cooperative Lander/Rover - Biomorphic Explorers

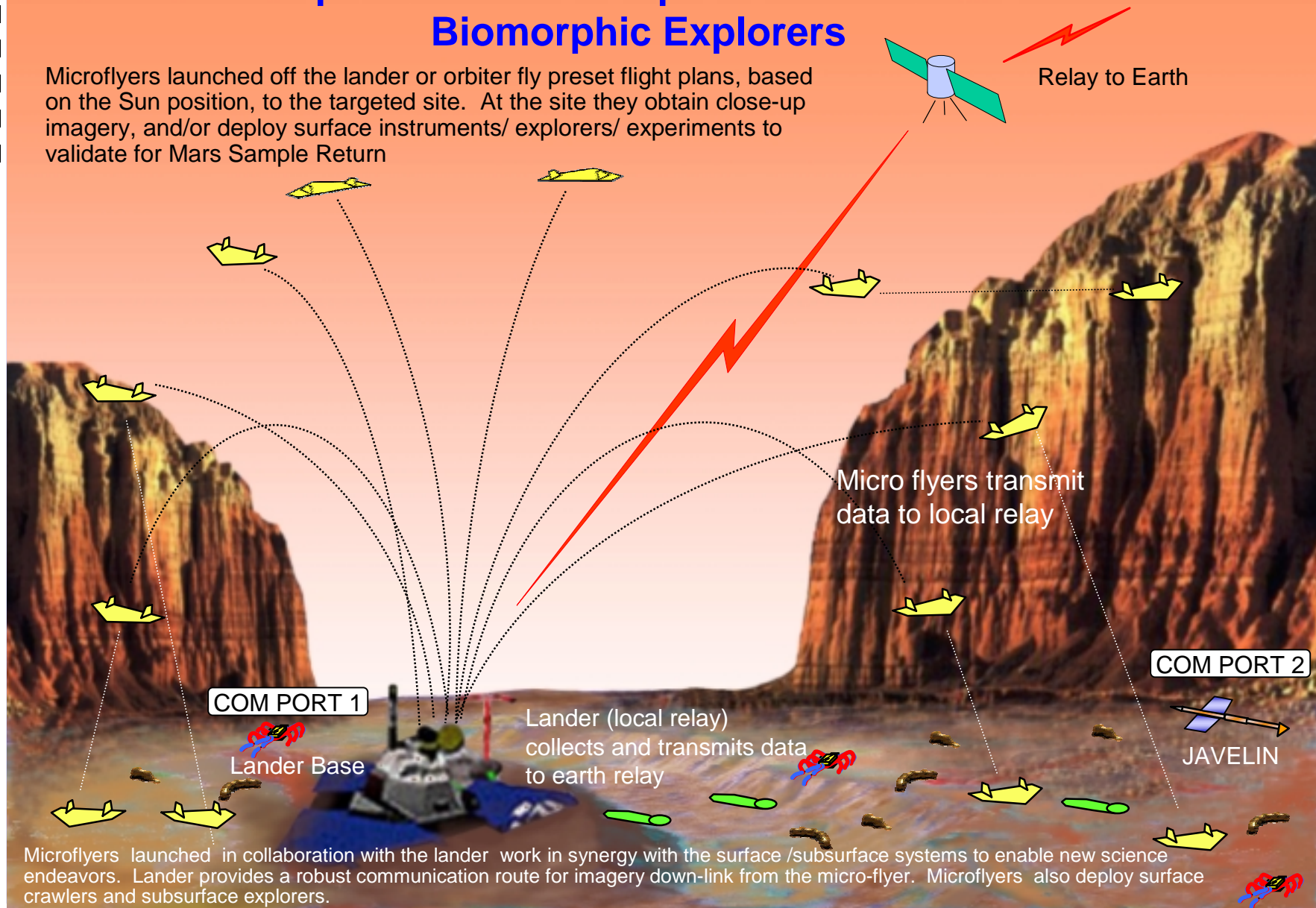
- An auxiliary payload of a Mars Orbiter (2-10 kg)
- Micro-gliders (4 - 20) launched/deployed from the orbiter
- Lander serves as a local relay for imagery/data downlink
- Micro-Glider provides:
 - Close-up imagery of sites of interest (~ 5-10 cm resolution)
 - Deploys Surface payload/experiments (20g - 500g)
 - In-flight Atmospheric Measurements
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- Future Missions - Competed Scout Missions (2007), Distributed Deployment and in-situ measurements- 2007 and beyond

Lander-Microglider Cooperative Mission Aerially Launched Microgliders



Biomorphic Mission: Cooperative Lander/Rover - Biomorphic Explorers

Microflyers launched off the lander or orbiter fly preset flight plans, based on the Sun position, to the targeted site. At the site they obtain close-up imagery, and/or deploy surface instruments/ explorers/ experiments to validate for Mars Sample Return



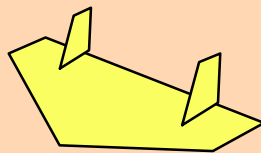
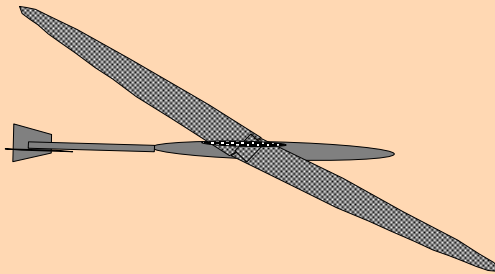
Microflyers launched in collaboration with the lander work in synergy with the surface /subsurface systems to enable new science endeavors. Lander provides a robust communication route for imagery down-link from the micro-flyer. Microflyers also deploy surface crawlers and subsurface explorers.

Surface Launched Microflyers: Options Comparison

- **Contamination Free Launch options**
 - Spring launched (massive, KE left over, complex possibly damaging recoil)
 - Electric launch options (power hungry)
 - electrically driven propeller (Mars atmosphere too thin)
 - electromagnetic gun
 - Inflate and release a balloon (complicated mechanism, thin atmosphere a challenge, susceptible to winds)
 - Pneumatic, compressed gas launch (simple mechanism, simple recoil, leading candidate)
- **Rocket Boosted launch (contaminants, HCl, nitrates etc.)**
a good option for application such as scouting where contamination is not an issue

Biomorphic Microflyers

- Small, simple, low-cost system ideal for distributed measurements, reconnaissance and wide-area dispersion of sensors and small experiments.
- Payload mass fraction 50% or higher.
 - small mass (100 g - 1000 g)
 - low radar cross section
 - larger numbers for given payload due to low mass
 - precision targeting to destination
 - amenable to cooperative behaviors
 - missions can use potential energy by deploying from existing craft at high altitude
 - Captures features of soaring birds, utilizing rising currents in the environment
 - Launch options: spring, compressed gas launch, electric, rocket boosted etc
 - *Adaptive Control, Adaptive Wings*
 - *Self Repair features*

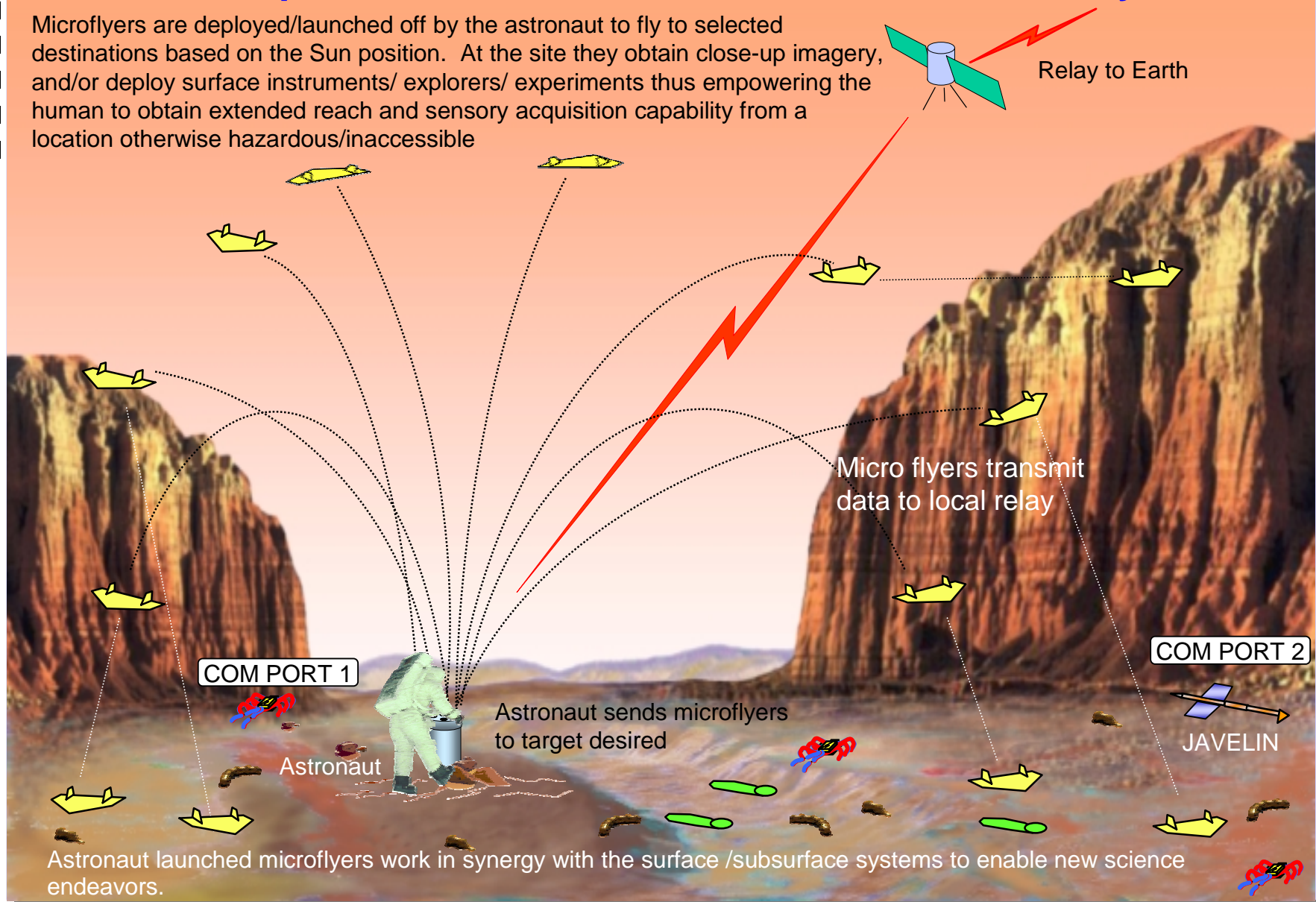


Science Objectives

- **Near Term 2007**
 - Image surface topography
 - Characterize terrain around lander
 - Identify rocks of interest for rover/lander
 - Distribution of Instruments/Experiments/Surface explorers to targeted sites
- **2007 - 2011**
 - Enable scouting, long range maps of areas of interest, and distributed deployment/in-situ measurements
 - Communication based on a self-organized, self-routing network, which is optimized dynamically using amorphous network of multiple hubs.
- **Long Term 2011 and beyond**
 - Co-operative Operation of a multitude of Explorers together to obtain imagery, and deploy surface payloads, Reconnaissance Mission
 - Astronaut Launched Microflyers: empowering the human to obtain extended reach and sensory acquisition capability from locations otherwise hazardous or inaccessible

Biomorphic Mission: Astronaut Launched Micro-Flyers

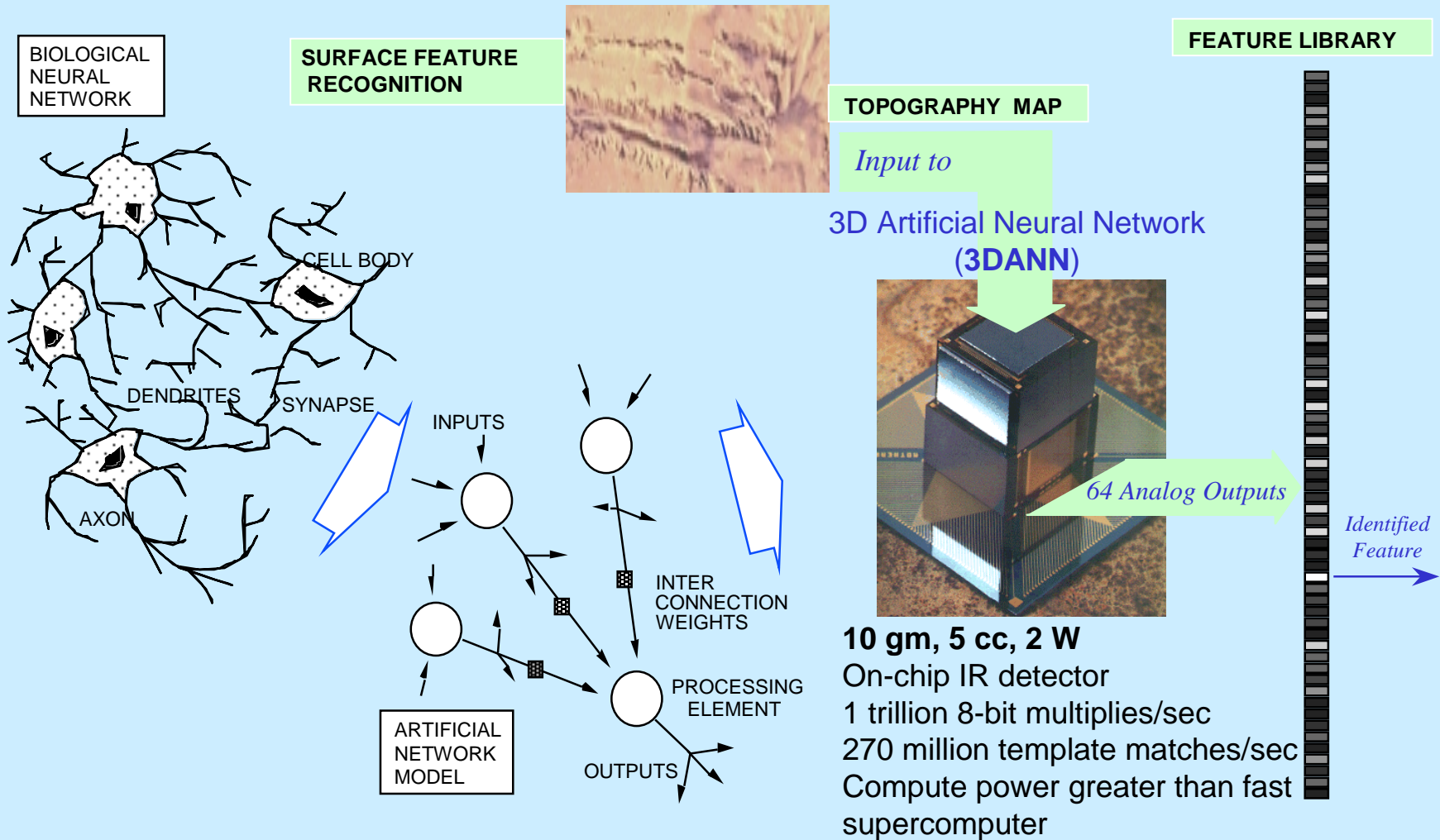
Microflyers are deployed/launched off by the astronaut to fly to selected destinations based on the Sun position. At the site they obtain close-up imagery, and/or deploy surface instruments/ explorers/ experiments thus empowering the human to obtain extended reach and sensory acquisition capability from a location otherwise hazardous/inaccessible



Enabling Processor for Surface Feature Recognition

Modeled after the massively parallel neural networks in human brain, 3DANN is a low-power, analog computing device capable of achieving human-like target recognition capability. The sugar-cube sized 3DANN processor has achieved an overall computing speed of ~ 1 trillion operations per second, consuming only ~ 8 watts of power (board (6W) + chip stack (2W)). This processing performance is ~ 3 orders of magnitude higher than the state-of-the-art image-processing on conventional digital machines (e.g. the Apple's recently introduced G4 computer which delivers ~ 1 billion operations per second, consuming ~ 200 watts of power). The processor can be trained to recognize geological features of interest and used to obtain real time processing of camera input imagery to identify surface features of interest. As a compact, low-power, intelligent processor on-board a space system, it would enable for the first time, real-time functions such as in-situ landing site selection with hazard avoidance, visual navigation, precision rendezvous and docking, and visually intelligent planetary robots/rovers capable of autonomous selection of scientifically interesting spots for maximum science return.

Enabling Processor for Surface Feature Recognition



JPL neural network chip design enables the 3DANN technology that delivers unprecedented processing speed for feature recognition (64 convolutions of 64x64 masks in 16 msec vs. 2 hours on state-of-the-art workstations)

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